



## ANALYSIS OF THE NATURE OF SCIENCE IN CHEMISTRY TEXTBOOKS ON THE TOPIC ACID-BASE EQUILIBRIUM: A CONTENT ANALYSIS

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### ABSTRACT

This study was conducted to describe aspects of the Nature of Science (NoS), its presentation, and its scores from chemistry textbooks used in Surakarta on acid-base equilibrium topics. This research was qualitative research with a content analysis method. Three high school chemistry textbooks for class XI from different publishers were analyzed by two raters based on ten aspects of the NoS. Interrater reliability was calculated using the Cohen Kappa. The results showed that a scientific law is the only aspect that is not included in the three textbooks A, B, and C. Other aspects of NoS contained in textbooks A and B are slightly different from textbook C. Textbooks A and B contain the same aspects: empirical, inferential, creative, theory-driven, tentative, scientific methods, scientific theories, social science, and the application of science in socio-cultural, while textbook C does not contain tentative and theory-driven aspects. The implicit-correct category dominates the presentation of the NoS aspects in the textbooks. Presentations with implicit-incorrect and explicit-incorrect categories were not found in this study. The scores obtained by textbooks A, B, and C based on the presentation of aspects of NoS are 9, 11, and 8, respectively, of the maximum total score that can be obtained of 30. It did not show the presence of the NoS aspects explicitly, correctly, consistently, and completely, so textbooks containing NoS explicitly are required. Teachers also need to guide students in interpreting NoS in learning.

**Keywords:** *nature of science (NoS), acid-base equilibrium, textbook, content analysis*

### INTRODUCTION

Scientific literacy is one of the skills needed by students in the 21st century [1]. According to the Program for International Student Assessment or PISA, scientific literacy is defined as the ability to use scientific knowledge to identify and investigate problems and then draw conclusions based on evidence to

understand, make decisions, and make changes to the universe through human activities [2]. This is in line with Holbrook and Rannikmaa's opinion about scientific literacy as the ability to understand science broadly and meaningfully so that it can be useful for personal and social life [3].

Scientific literacy is the main goal of science education held around the world which is realized through understanding the

nature of science (NoS) [4,5]. In Indonesia, the development of students' scientific literacy has been accommodated in the 2013 Curriculum, which uses a scientific approach. However, the scientific literacy achievement of Indonesian students is still relatively low. Based on PISA 2018, Indonesia has average scores in all three aspects of the PISA assessment: reading, mathematics, and science, respectively, 371, 379, and 396 [6].

Nature of science (NoS) is defined as a way of acquiring knowledge or values and beliefs inherent in developing and validating scientific knowledge [7]. The nature of science (NoS) is an inherent aspect of developing science, and understanding the nature of science is an important component of scientific literacy [8]. In recent years, the role of NoS in supporting scientific literacy has been widely institutionalized in international curriculum standards [9]. An understanding of NoS can facilitate students to understand science content better and foster interest in science [10]. Students' understanding of NoS can be influenced by various components of science learning, one of which is textbooks which are the main learning resources.

As an important part of scientific literacy, NoS is an important dimension that must be possessed in science textbooks, including chemistry [11]. The many studies that have been carried out in the last 15 years regarding the nature of science published in science textbooks, especially chemistry [12]. The representation of aspects of NoS explicitly in textbooks used in the teaching and learning process is one of the efforts that can be made to increase understanding of

NoS [13]. Research using content analysis procedures on aspects of NoS has been carried out by several previous researchers, both inside and outside Indonesia. However, the results of previous studies show that there is still a lack of content in the NoS aspect of chemistry textbooks used as learning resources [7,14,15] and limited to chemistry textbooks used in a particular area. For that, we need an analysis of the nature of science to other chemistry textbooks.

Learning chemistry as part of science education cannot be separated from the NoS, which requires discussing scientific problems. Several studies have been carried out for chemistry textbooks, such as on atomic structure [7,16,17], molecular kinetic theory, and gas law [7]. Another important topic for analysis related to NoS is acid-base equilibrium [18]. Acid-base equilibrium is a very important topic to be learned by students because it three things, acids and bases are commonly known in daily life, both by students and the community in general, such as the terms gastric acidity and antacids, acids and bases are often found in social science issues, and acids and bases offer a scientific history that can be used to improve understanding of the acid-base model, its limitations, and, as a consequence, the conditions necessary to select each model. Acid-base teaching uses the nature of science approach explicitly and implicitly to improve students' understanding of acid-base [19]. Seeing the importance of NoS in chemistry textbooks, especially on the acid-base equilibrium topic, an analysis of the NoS in this topic is needed to facilitate students' learning and understanding of the NoS.

Research on content analysis on NoS in chemistry textbooks at schools has been carried out by several previous researchers [7,14,15,23]. Seeing the importance of NoS in school chemistry textbooks, a NoS analysis needs to be carried out on school chemistry textbooks that have never been studied before concerning NoS. Topics that have never been discussed about NoS

## METHODS

### Research Map

This research employed a qualitative research design that utilized a content analysis method. Content analysis is a research method that provides a systematic and objective way to make valid conclusions from verbal, visual, or written data to describe and measure certain phenomena [18]. The overall process of this research is illustrated in Figure 1. First, the content of each selected textbook, including textbook text, graphs, tables, historical narrative, experimental activities, and student tasks, is inspected.

This research sample was three high school chemistry textbooks selected using the purposive sampling technique. From interviews conducted with several teachers and students at state senior high schools in Surakarta, it was found that there were three most widely used textbooks, coded as textbooks A, B, and C. The topic chosen for analysis is acid-base equilibrium. The topic was chosen because it is closely related to everyday life and generally provides the history of science in the presentation of the topic so that it has the potential to contain aspects of NoS [19].

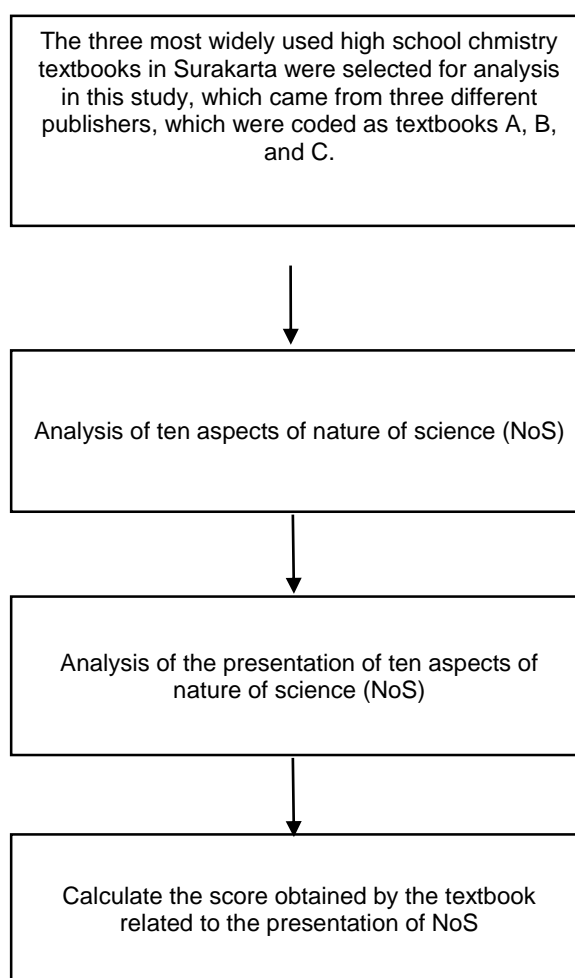


Figure 1. Analysis flowchart of NoS

### Instruments and Indicators

Textbook content analysis was carried out based on ten aspects of NoS as described in Table 1, which were also adopted from previous studies on NoS analysis in textbooks: empirical, inferential, creative, theory-driven, tentative, scientific method, scientific theory, scientific law, social science, and the application of science in socio-culture by citing parts of the textbooks that are relevant to aspects of the NoS [15].

Table 1. Explication of the NoS aspects targeted in the analysis of the selected textbooks [15]

NoS aspect	Aspect descriptions in the textbook analysis
Empirical	Scientific knowledge or statements in science are based on observations of natural phenomena.
Inferential	A conclusion from a phenomenon that cannot be observed directly or a statement about a phenomenon that cannot be directly accessed by the five senses originating from an activity.
Creative	Scientific knowledge is generated by involving the creativity or imagination of the scientist.
Theory-driven	Previous theories influence the development of scientific knowledge.
Tentative	Scientific knowledge can change as new evidence is discovered through conceptual and technological advances or by reinterpreting existing theories.
Scientific method	The methods used to acquire scientific knowledge include observing, measuring, comparing, testing, speculating, making hypotheses, creating ideas, and forming theories and explanations.
Scientific theory	Explanation of an observed phenomenon or regularity in the phenomenon.
Scientific law	A descriptive statement that explains the relationship between the observed phenomena.
Social science	The role of society in developing scientific knowledge.
The application of science in socio-culture	Application of scientific knowledge in daily life or various areas of life.

## Data Analysis

In this research, two raters were used to look at the content of NoS in textbooks on the topic of acid-base balance. Some aspects include quoting sentences, paragraphs, tables, pictures, graphs, and student activities related to one or more

aspects of NoS. The quotations obtained were analyzed based on the way they were presented, which consisted of 4 categories: explicit-true, implicit-true, implicit-false, and explicit-false, as shown in Table 2. Then these quotations were scored according to the scoring rubric in Table 3 [15].

Table 2. NoS aspect presentation category

Presentation category	Description
Explicit-correct	The NoS aspect is presented explicitly through an explanation of the NoS aspect concept directly (can also be accompanied by examples related to the NoS aspect) in the analyzed quotation and following the definition/concept of NoS.
Implicit-correct	NoS aspects are presented implicitly through examples related to NoS aspects in the analyzed quotations and following the definition/concept of NoS.
Implicit-incorrect	NoS aspects are presented implicitly through examples related to NoS aspects in the analyzed quotations but not following the definition/concept of NoS
Explicit-incorrect	The NoS aspect is presented explicitly through a direct explanation of the NoS aspect concept (can also be accompanied by examples related to the NoS aspect) in the analyzed quotation. Still, it does not follow the definition/concept of NoS.

The rater consists of two selected people with the qualifications of one rater who has experience in research in the NoS field

and is subjected to a simple test to check understanding regarding NoS. The second rater is an expert who has experience writing

textbooks for high school chemistry and understands NoS aspects well. The level of agreement between raters was calculated using the Cohen kappa [20]. The results of the analysis and conclusions are described as the findings obtained from the research.

## RESULTS AND DISCUSSION

### Results

All raters carried out an analysis of the aspect of NoS. The rater was selected based on "having researched content analysis of NoS in high school chemistry textbooks". The second rater is a teacher who has experience writing textbooks for high school chemistry and understands NoS. The results of calculating the cohen kappa value between the researcher and the rater for each textbook can be seen in Table 3.

Table 3. Result of cohen kappa

No.	Textbook	Cohen Kappa	Category
1	A	1, 000	Very good
2	B	1,000	Very good
3	C	0.968	Very good
Average		0.989	Very good

Table 4. Aspects of NoS included in textbooks

NoS Aspect	Textbook		
	A	B	C
Empirical	✓	✓	✓
Inferential	✓	✓	✓
Creative	✓	✓	✓
Theory-driven	✓	✓	-
Tentative	✓	✓	-
Scientific Method	✓	✓	✓
Scientific Theory	✓	✓	✓
Scientific Law	-	-	-
Social Science	✓	✓	✓
Application of Science in Social Culture	✓	✓	✓

The results of NoS aspects contained in each textbook can be seen in Table 4. Table 5 shows that textbooks A and B contain aspects of the same NoS, while textbook C contains aspects of NoS, which are slightly different from the two previous textbooks. For example, based on ten analyzed aspects of NoS, textbooks A and C contain nine aspects, while textbook C contains seven aspects of NoS.

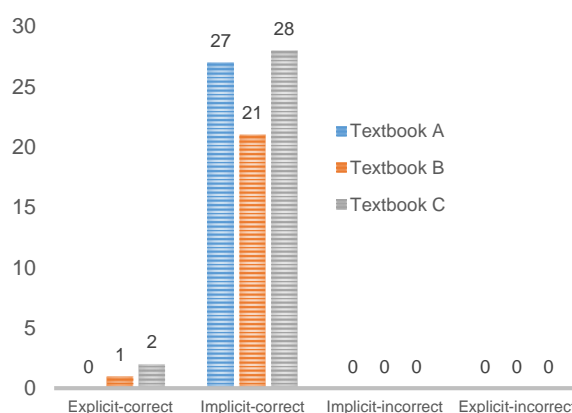


Figure 2. Graph of the number of quotations based on the presentation category of the NoS aspects in textbooks.

The presentation of aspects of NoS is seen from the presentation of the quotes that represent it. Aspects of the NoS can be presented in the quotes by considering its approach and representation. This study has four categories of presentation of the NoS aspects: explicit-correct, implicit-correct, implicit-incorrect, and explicit-incorrect [18]. Table 6 presents quotes and examples of activities from the textbooks to illustrate the presentation of some NoS aspects in textbooks. The number of quotations obtained from the analysis based on their presentation of each aspect of the nature of science in textbooks A, B, and C can be seen in the graph presented in Figure 2.

Table 5. Examples of textbook excerpts corresponding to the presentations of some NoS aspects analyzed

NoS aspect	Categories of presentation	Illustrative quote
Empirical	Implicit-correct	<p>“Based on Activity 5.3, if you pay attention, it is obtained the fact that salt in water can form a solution that is acidic, basic, or neutral.” (Textbook A, p. 174)</p> <p>“If a salt is dissolved in water, then the pH is measured. Will give varying pH values as shown in Table 6.8.” (Textbook B, p. 198)</p> <p>“Based on the activity, you can distinguish the strength acid-base based on the number of gas bubbles formed and the speed of the reaction time.” (Textbook C, p. 152)</p>
Inferential	Implicit-correct	<p>“Based on Activity 5.3, if you pay attention, it is found that salt in water can form an acidic, basic, or neutral solution. Previously, it has been explained that salt consists of cations and anions. If salt is dissolved in water, it will ionize into its constituent ions. The reaction between salt ions can produce <math>H^+</math> or <math>OH^-</math> ions. This causes a salt solution to be acidic, basic, or neutral. This reaction is known as a hydrolysis reaction.” (Textbook A, p. 174)</p> <p>“When salt is dissolved in water, it will be ionized to produce cations and anions. The cations and anions can react with water. That event is called hydrolysis.” (Textbook B, p. 199)</p> <p>“Salt is obtained from the reaction of an acid with a base. When dissolved in water, the salt dissociates into its ions and forms an equilibrium reaction. The interaction of salt ions with water determines a salt solution's properties.” (Textbook C, p. 171)</p>
Creative	Implicit-correct	<p>“The explanation of acids and bases, according to Svante Arrhenius, is not” satisfactory for explaining the acid-base properties of a solution that is free of water or the solvent is not water. Based on this fact, Johannes Bronsted and Thomas Lewry separately proposed that those who play a role in giving acidic and basic properties of a solution are the <math>H^+</math> ion or protons.” (Textbook A, p. 153)</p> <p>“Bronsted-Lowry explanation is quite useful for acid-base reactions in water. This explanation differs from the Arrhenius definition because it can be applied to solvents other than water.” (Textbook B, p. 167-168)</p> <p>“The concentration of <math>H^+</math> ions in any solution of a weak acid is very small. Sorensen avoided using very small numbers; a biochemist from Denmark proposed the term pH in 1909, referring to the “potential of hydrogen ions”. He defined pH as the negative of the logarithm.” (Textbook C, p. 155)</p>
Theory-driven	Implicit-correct	<p>“The concept of acid-base developed by Lewis is based on a coordinating covalent bond. Atoms or species that donate an electron pair to form a bond coordination covalent will act as a base. In contrast, The atom, molecule, or species that accepts electrons is called as acid.” (Textbook A, p. 155)</p> <p>“The concept of G.N. Lewis (1923) could include the concepts of Arrhenius and Bronsted-Lowry. A base with a lone pair of electrons (not a bonding electron pair) can donate to form a coordinating covalent bond. Acids can have the ability to accept a lone pair of electrons. Lewis used the principle of coordination bonds to describe acid-base reactions. Thus, this concept does not use the concept of a proton but uses the concept of an electron pair.” (Textbook B, p. 168)</p>
Tentative	Explicit-correct	<p>“The theory of acids and bases has developed along with the development of science, including the Arrhenius acid-base theory, Bronsted-Lowry acid-base theory, and GN Lewis acid-base theory.” (Textbook B, p. 167)</p>
	Implicit-correct	<p>“The concept of acid-base, according to Bronsted Lowry has limitations, especially in explaining reactions involving compounds without protons (<math>H^+</math>), for example, reactions between <math>NH_3</math> and <math>BF_3</math> compounds, as well as some reactions involving complex compounds. In 1932, the chemist G. N. Lewis proposed a new concept of acids and bases so that Lewis acids and Lewis bases were known. (Textbook A, p. 154)</p>
Scientific Method	Implicit-correct	<p>“Activity 5.2 Estimating the pH of a Solution with Several Indicators...” (Textbook A, p. 170)</p>

NoS aspect	Categories of presentation	Illustrative quote
Scientific Theory	Implicit-correct	"Experiment 6.1 Purpose: observe the color change trajectory of various indicators roughly acid-base..." (Textbook B, p. 172) "Let's Explore Analyzing the Properties of Salts from Acid-Base Titration Graphs..." (Textbook C, p. 175)
		"The nature of the acid and base of a solution can be explained using several theories, namely the Arrhenius acid-base theory, Bronsted Lowry theory of acids and bases, and G.N's theory of acids and bases Lewis." (Textbook A, p. 151) "A Swedish chemist named Svante Arrhenius (1859-1927) 1884 defined acids and bases. According to Arrhenius: An acid is a substance that, when dissolved in water, can produce H <sup>+</sup> ions (or H <sub>3</sub> O <sup>+</sup> ). Language is a substance that, when dissolved in water, produces ions OH <sup>-</sup> (l)." (Textbook B, p. 167) "The Lewis acid-base theory was put forward by an American chemist named G.N. Lewis in 1932. This theory states that a base is a substance with one or more lone pairs of electrons that can be donated to other substances to form a coordinating covalent bond. Meanwhile, an acid is a substance that can accept the electron pair or an electron acceptor." (Textbook C, p. 147)
Social Science	Implicit-correct	"In 1932, the chemist G. N. Lewis proposed a new concept of acids and bases so that they were known as Lewis acids and Lewis bases." (Textbook A, p. 154) "Arrhenius won the Nobel Prize in Chemistry in 1903." (Textbook B, p. 167) "In 1884, Svante Arrhenius put forward the theory of acids and bases known as the Arrhenius acid-base theory." (Textbook C, p. 146)
Application of Science in Social Culture	Explicit-correct	"Application of Hydrolysis in Daily Life Hydrolysis reactions play a role in everyday life, including in the purification of drinking water, the use of fertilizers, and bleaching clothes." (Textbook C, p. 183)
	Implicit-correct	Chemical info: pH as an Indicator of Wastewater Quality" (Textbook A, p. 214) "Buffer solutions have an important role in the pharmaceutical industry. For eye drops, injections, and infusions, the pH must be adjusted to the pH of body fluids so that when used, it does not cause a negative impact." (Textbook B, p. 198) "Turn acidic soil into neutral soil that is good for plant growth. .... Wood-burning ash contains potassium hydroxide (KOH), which is alkaline. If the ash is sprinkled on acidic soil, it will be neutral." (Textbook C, p. 163)

Table 6. Score on the NoS aspect of chemistry textbooks for class XI topic on acid-base equilibrium topic

Aspect NoS	Score (Teksbook)		
	A	B	C
Empirical	1	1	1
Inferential	1	1	1
Creative	1	1	1
Theory-driven	1	1	0
Tentative	1	3	0
Scientific Method	1	1	1
Scientific Theory	1	1	1
Scientific Law	0	0	0
Social Science	1	1	1
Application of Science in Social Culture	1	1	2
<b>Total</b>	<b>9</b>	<b>11</b>	<b>8</b>

Quotations that show the same NoS aspects are grouped as a topic for determining the score. Each aspect of the NoS is given a score according to the scoring rubric. The scores for each aspect of the NoS in each textbook can be seen in [Table 6](#).

## Discussion

Based on the results, textbooks A and B contain aspects of the same NoS, while textbook C contains aspects of NoS, which are slightly different from the two previous textbooks. It can be caused by how the topic is written in the textbook, which is so closely

related to the authors' style and the author's interest in NoS that it allows the same topic to be delivered in different languages and ways [21]. The three textbooks have included aspects of the NoS on acid-base equilibrium topic, although they are not yet complete. A scientific law is the only aspect of the NoS that is not included in the three analysed textbooks because there are not enough passages to show aspects of scientific law, either explicitly or implicitly. Aspects of the NoS can be more easily integrated into chemistry topics, such as the development of atoms and the periodic system but become more challenging in other topics, such as chemical kinetics and equilibrium [22].

The presentation of aspects of NoS is shown through the presentation of textbook content by referring to its approach and representation. The approach used in dealing with aspects of the NoS in textbooks can be in the form of explicit and implicit approaches. The explicit approach explains that the NoS aspect is mentioned explicitly by the textbook's author, accompanied by explanations and examples related to the NoS aspect, so that students as readers can immediately know and understand the NoS aspect referred to by the author of the textbook [21].

Presentation of the NoS aspect with an explicit approach provides a fairly clear discussion description or reflective opportunity to help students form a meta-understanding of the characteristics, development, and validation of scientific knowledge [7,23]. The presentation of the NoS aspect with an implicit approach explains that the NoS aspect is implied

without a clear and explicit statement about the NoS aspect referred to by the author of the textbook [21]. The presentation of the NoS aspect with an implicit approach can also be interpreted as the text topic containing the NoS, which requires independent reflection or reflection guided by the teacher to understand the NoS aspect [7,23]. Meanwhile, based on its representation, aspects of the NoS can be presented correctly or incorrectly (misrepresentation). The presentation of the NoS aspect correctly is defined as the presentation of epistemological ideas from the NoS aspect that follows the idea or description of the NoS aspect in question. In contrast, the incorrect presentation (misrepresentation) is defined as the presentation of epistemological ideas from the NoS aspect that does not follow the idea or description of the nature of the science aspect in question so that it can lead to misconceptions about the nature of science [7,23].

Based on the results, most of the presentations of NoS quotations are categorized as implicit-correct. In textbook A, all quotations that present aspects of NoS are categorized as implicit-correct, with a total of 27 quotations. In textbook B, 21 quotations present aspects of NoS that are categorized as implicit-correct, and one quote is categorized as explicit-correct. In textbook C, 28 quotations present aspects of NoS that are categorized as implicit-correct, and two quotes are categorized as explicit-correct. The quote found in textbook B, page 167 (see [Table 6](#)) conveys a direct description of the



tentative aspect so that it is categorized as explicit-correct [15].

Meanwhile, the quote found in textbook A, page 154 (see Table 5) shows examples from fragments of the history of the development of acid-base theory. The epistemological idea of tentative itself is not a straightforward and direct explanation, so the reader needs to reflect first to understand tentative aspects [23]. The results of this study follow previous research that the implicit approach is the most widely used in chemistry textbooks in presenting the NoS compared to the explicit approach [21,22]. Research conducted by [15] on the high school physics textbooks analyzed was dominated by an implicit approach to dealing with aspects of the NoS.

Most aspects of NoS are categorized as true implicit, according to a score of 1 on most aspects of NoS for the three textbooks analyzed, as presented in Table 6. Based on the scoring rubric, a score of 1 indicates that all quotations conveying aspects of the NoS target are categorized as implicit-correct [15]. The total scores for ten aspects of NoS in each textbook A, B, and C obtained in this study are 9, 11, and 8. As seen in Table 6, textbooks A and B contain the same aspects of NoS, as many as nine aspects, while textbook C contains seven of NoS. Even though it has the same number of NoS aspects, textbook B gets a higher score than textbook A. It can be caused by how the topic is written in the textbook, which is so closely related to the authors' style and the author's interest in NoS that it allows the same topic to be delivered in different languages and ways [21]. The total score obtained by three textbooks is still far

from the maximum score of 30, which indicates that the NoS aspect is explicitly and completely contained in a textbook [15]. The discovery of an implicit approach to the presentation of most of the NoS quotes makes the teacher's role necessary to help students understand the nature of science. Teachers could convey ideas or descriptions of aspects of NoS or conduct discussions about aspects of NoS related to the topic being taught and inquiry activities that are being carried out by involving the active participation of students [22].

## CONCLUSION

Most aspects of the nature of science Most aspects of natural science properties have been found in acid-base equilibrium materials from the three most widely used chemistry textbooks for class XI. The only aspect of the nature of science that has not been discovered is a scientific law. Textbooks A and B contain nine aspects of the NoS, while textbook C contains seven aspects. The overall scores obtained by textbooks A, B, and C were not negative. In other words, there were no misrepresentations or wrong concepts regarding aspects of the NoS contained in the three textbooks, so they could be used to help students understand the NoS. However, the majority of approaches found in presenting aspects of the nature of natural science are implicit (with true implicit categories). In its development, learning about natural aspects of natural science requires guidance from the teacher. Teachers can hold discussions about aspects of the NoS with the topics being taught and inquiry activities carried out by involving active student participation.

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